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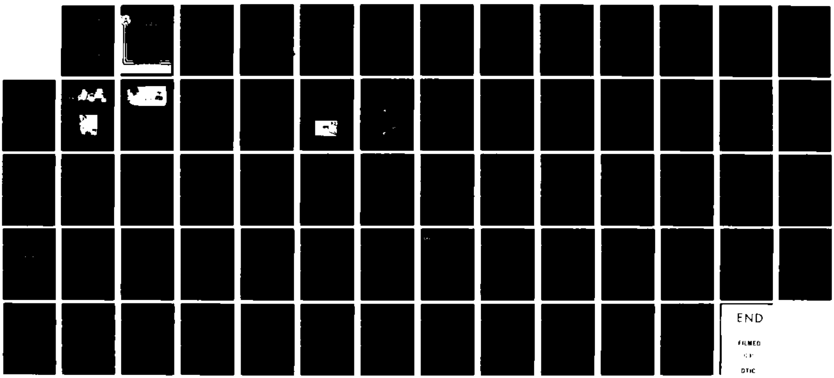

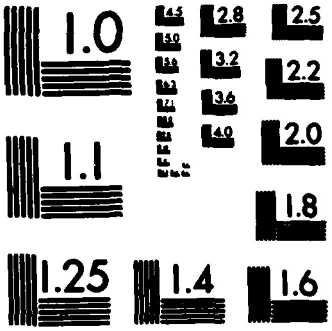

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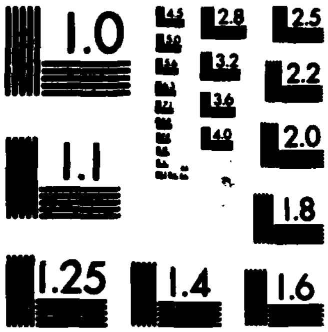

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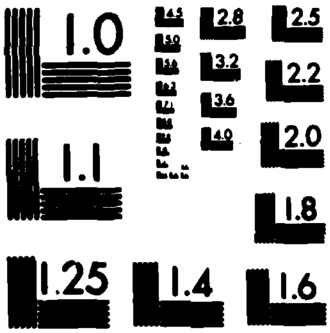

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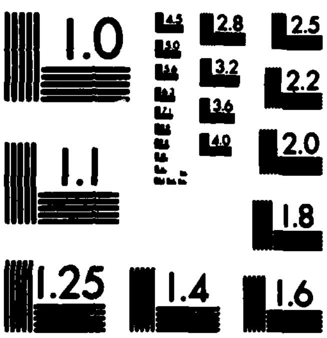

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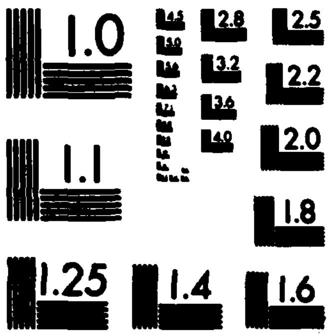

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PRELIMINARY STUDY ON SCANNING TECHNIQUES USED BY U.S. COAST GUARD LOOKOUTS DURING SEARCH AND RESCUE MISSIONS

By

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BIOMEDICAL APPLICATIONS RESEARCH DIVISION

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20. Abstract:

This research was a cooperative study undertaken by the US Coast Guard Research and Development Center (USCG R&D) and the US Army Aeromedical Research Laboratory (USAARL). Eye performance data were collected from Coast Guard personnel performing as lookouts during simulated search and rescue missions on HH-3F helicopters, a 210-foot cutter, and an 82-foot cutter. Visual performance was measured by means of NAC Eye Mark Recorder Systems during the Winter 1981 Visual Detection Experiment conducted by the USCG R&D Center in the Gulf of Mexico off of Panama City, Florida, during January and February 1981. The visual performance measures were analyzed to determine the scanning patterns utilized by the various lookouts. Based upon this initial study, it appears that most personnel spend about one half of search time on only one segment of their total assigned viewing area. For example, pilots and copilots spend most of their time looking out their respective front windows. For the surface vessels, the subjects seemed to display the condition termed "eye lock"--that is, a lookout would position his eyes and keep them stationary, allowing the movement of the search vessel to dictate his scan path. The scanner patterns prescribed in the US Coast Guard training manuals were used infrequently; rather the observers followed the outline of structures within their fields of view.

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INTRODUCTION

One of the primary missions of the United States Coast Guard (USCG) is search for and rescue (SAR) of personnel and equipment stranded on U.S. waterways, the Gulf of Mexico, and bordering oceans. In fiscal year (FY) 1980, the USCG responded to over 73,000 calls for assistance. Twenty-nine percent of these calls (35,797 man-hours) involved searching for vessels or personnel. Of these calls, 74 percent were successful and a total of 6,868 people were rescued; however, the other 26 percent of the calls were not successful and 1,821 people were lost (US Coast Guard SAR Statistics, 1980). The USCG is continually developing and testing new equipment and evaluating lookout/scanner training methods for its personnel (Edwards, Osmer, Mazour, and Hover, 1981) in an effort to upgrade SAR effectiveness.

All personnel aboard a USCG sea vessel or aircraft are trained as observers according to the *US Coast Guard Shipboard Lookout Manual* (CG-414). Observer training teaches basic search techniques, lookout organization, distinction between horizon and surface search tasks, night scanning techniques, equipment use and sightings report procedures. In this context, the skill of an observer is determined by how well he uses his eyes. Coast Guard training emphasizes that observers make small saccadic eye movements as if reading a line of type. The search area or quadrant is to be scanned in a snake-like pattern, with 5-second intervals per 5 degrees field of view (*US Coast Guard Shipboard Lookout Manual,* CG-414).

Though such a systematic method should provide complete coverage of an area being searched, many objects or targets remain undetected. A review of research literature shows that factors affecting target detection performance can be classified according to three categories: (1) target-related characteristics, (2) observer-related factors, and (3) environmental conditions.

The USCG has reported that the target-related characteristics of color, size, and shape affect the probability of detecting a target (Edwards et al., 1981). Orange rafts are detected more frequently than black rafts; presumably due to the increased contrast between target and background. Bloomfield (1979) examined the ease with which subjects were able to discriminate between embedded target displays on the basis of color and texture. The color display consisted of five types of vinyl floor tiles in six different colors: yellow, white, tan, green, blue, and red. A monochrome display of textures included oriental straw cloth, woolen cloth, pigskin, beach sand, and expanded mica. Data collected from the 28 observers showed that the targets contained in the color display were more easily located in the order of red, blue, green, tan, and white. Results of the texture display phase showed that all observers found the oriental straw cloth target with ease, but no pattern of results emerged from the remaining targets. Other studies, such as "Searching for Traffic Signals While Engaged in Compensatory Tracking" (Noble and Sanders, 1980) and "Effective Training for Target Identification Under Degraded

Conditions" (Cockrell, 1979), have shown color to have a strong main effect during search.

The second target detection variable, target size, cited by the USCG, was a prime question addressed in a study by Ward in 1979. Three sizes of a bright spot were sequentially superimposed onto a luminous background, and then both the spots and the light from the luminous background were directed into the viewer's right eye. The spots moved across the background or screen at the rate of 0, 3, 60, and 120 degrees per second. Analysis of the data showed that time to detection decreased as target size increased. There was also a tendency for time to detection of large targets to decrease with velocity, but the direction of movement, either horizontal or vertical, had little effect on detection.

A second variable, observer-related factors, reported in the literature as affecting target detection, includes visual acuity and perception, fatigue, training and experience level, and physical and psychological stress. For the purposes of this report, discussion of observer-related factors are limited to visual acuity and perception with the visual acuity and perception being further categorized as eye movement patterns, fixations, pursuit eye movements, scanning techniques, peripheral vision, and head/eye movements. Stern and Bynum (1970) investigated aspects of both visual perception and experience level by comparing eye movements of instructor pilots and student pilots during a 50-minute cross-country flight. Data collected showed that for all measures there was a significant change in visual activity as a function of time on task. There was also a decrease in visual search activity in both the horizontal and vertical planes though the skilled pilots continued horizontal searches for a longer percentage of time than did the novice pilots.

Data resulting from a study conducted by Gresty and Leech in 1977 indicated that continual head movement in pursuit tasks was not an aid to performance and, in fact, may be detrimental. Only at the lower frequencies of sinusoidal target oscillation did the sum of head and eye movement resemble the target motion. Similarly, Barnes and Sommerville (1978) instructed subjects to line up a helmet-mounted sight over randomly illuminated target lights. Tracking the target lights with the helmet-mounted sight produced a characteristic pattern of the head movement being initiated 300-400 milliseconds after presentation of the target. The continuous target condition used during the experiment showed that it was very difficult to faithfully maintain fixation of the sight during head motion due to the initial saccadic or rapid, jerky eye movement in the direction of the head movement.

Target detection during a test of peripheral vision conducted by Berkhout Phillips, and Breidenbach (1979) was hampered by target/background contrast, image sharpness, rate of motion, and subject age. The central vision test phase showed that only low brightness contrast between target and background interfered with correct target detection. Eye fixation, another influence on visual acuity, was examined by Bozkov, Bohdanecky, and Radil-Weiss in 1977. One of the two questions addressed by the study involved determining which features of a stimulus were most fixated upon by the test subjects. The

remaining question was concerned with the distribution of fixations over the surface of different sizes of angles. Analysis of the data demonstrated that the angles of the stimulus features were fixated about 70 percent and that those fixations shifted towards the vertex of the obtuse angles as compared with the acute ones. The derived conclusion stated that "any fixation is a result of a preprogramed 'balistic' [sic] goal directed eye movement" and that the levels of selecting this goal are (1) psychological features determining subpatterns and (2) a peripheral feature based on local point-by-point representation of the input objects.

Environmental conditions are a third category which plays a large part in the ease with which a target is detected. Windspeed and swell height, for instance, were shown in a US Coast Guard report by Edwards et al. (1981) to have a linear relationship with each 1-foot increase in swell height being associated with a 5-knot increase in windspeed. A wave height of 3 feet or greater can result in a wave trough large enough to completely hide a small target. Waves of this size are not uncommon. They can be produced, for example, by a 15-knot wind blowing over a 30-nautical mile ocean surface for approximately 5 hours (H.O. Pub 603). Coast Guard observers, particularly aircrewmen, are also subject to distractions involved with maintaining the status of the search vehicle. Safety checks have to be made, courses charted, and radios monitored, in addition to the task of flying the aircraft.

Huntoon, Schohan, and Shvern (1979) showed that target detection was impaired by the performance of auxiliary tasks during a visual search exercise utilizing a simulated remotely piloted vehicle. Three classes of targets were used in a simulated reconnaissance mission: tanks, trucks, and self-propelled anti-aircraft artillery. Each appeared in open and cluttered settings on a TV monitor. While performing a series of auxiliary tasks, subjects searched the screen and located the target. In order to complete the exercise, subjects were instructed to slew the camera to center the target on the screen and zoom in to get a more detailed view. Results showed subject performance was affected by the required division of attention.

In summary, target detection performance is affected by variables ranging from target attributes such as color and size to environmental conditions which physically limit or distort the observer's sighting capabilities. Ultimately, however, successful search and rescue missions depend upon human vigilance. Learned scanning/lookout techniques and a high level of proficiency combine to produce vigilant observers but is vigilance inversely proportional to the amount of time spent searching? Can any eye movement, eye fixation, or head movement patterns of the experienced observer be distinguished from the novice observer? Are there noticeable changes in eye movements and observer responses just prior to target detections? Is the step-like scanning technique taught by USCG being used by observers, and is the method superior to idiosyncratic techniques used by some observers? These questions were addressed by members of the US Army Aeromedical Research Laboratory (USAARL) Crew Stress/Workload Team during a joint project conducted with the USCG Research and Development Center.

METHOD

:s for this investigation were volunteers from the sea and air of the USCG; 16 were from aviation units and 26 from surface units. n subjects were crewmen assigned to two USCG HH-3F rotary wing om Coast Guard (CG) Air Station, Clearwater, Florida, and two USCG aft from CG Air Station, New Orleans, Louisiana. The sea vessel re selected from the crews of three participating CG surface he 82-foot cutters, CGC Point VERDE (WPB 82311) and CGC Point LOBOS , and the 210-foot cutter, CGC DEPENDABLE (WMEC 626). All subjects hat they were familiar with the USCG's method of search and rescue in *Shipboard Lookout Manual,* CG 414. Table 1 groups the subjects o search vehicle and lists each subject's age and years of search experience along with the mean and standard deviation.

raphical data questionnaire was completed by each subject along nteer agreement form and a release for unconditional use of picture A copy of each form completed by participants is contained in Afterwards, USAARL personnel administered a vision test using a on tester,* an optical instrument designed to measure levels of ty. Subjects were tested for visual acuity at distal ("FAR") and NEAR") points, deficiencies in color perception "FAR," lateral and oria "FAR," and depth perception. The "FAR" tests were presented al distance of 20 feet, an average of 15 degrees below the hori- e. The "NEAR" tests had an optical distance of 14 inches and proximately 45 degrees below the horizontal plane. The brightness de illumination was 10 to 15 footlamberts diffused to give uniform over the entire area.

s NAC Eye Mark Recorder systems were used to collect oculomotor measures of participants assigned to either of the three types of vehicles used in this study. Each system shown in Figure 1 (1) a NAC Eye Mark Recorder mask,* (2) LOCAM high speed motion era,* (3) time code generator with event marker, (4) modified PBH-2 icle crewman's helmet (tanker's helmet), and (5) multiple extension aircraft), shown in Figure 2, or a modified Army lightweight camera ALCE) pack frame (on surface vessel), shown in Figure 3.

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tes product manufacturer listed in equipment and manufacturer list,

TABLE 1

OBSERVER AGE AND SAR EXPERIENCE BY SEARCH VEHICLE

	HH-3F Helicopter		82 Ft Cutter (WPB)		210 Ft Cutter (WMEC)	
	Age	Experience (Years)	Age	Experience (Years)	Age	Experience (Years)
	36	20.00	33	6.00	35	14.00
	34	13.00	23	5.50	39	6.00
	36	12.00	42	4.00	33	2.50
	29	9.00	23	4.00	22	1.50
	28	6.00	28	3.00	19	1.25
	28	6.00	26	3.00	21	1.00
	27	5.50	19	.50	22	.66
	31	5.00	19	.25	32	.50
	27	4.00	25	0.00	21	.50
	24	4.00	21	0.00	29	0.00
	23	4.00	18	0.00	24	0.00
	29	3.50			20	0.00
	27	3.50			19	0.00
	21	2.00			19	0.00
	21	1.50			18	0.00
	27	1.00				
Mean	28	6.25	25.18	2.39	24.87	1.86
Std	4.50	5.01	7.12	2.32	6.85	3.70

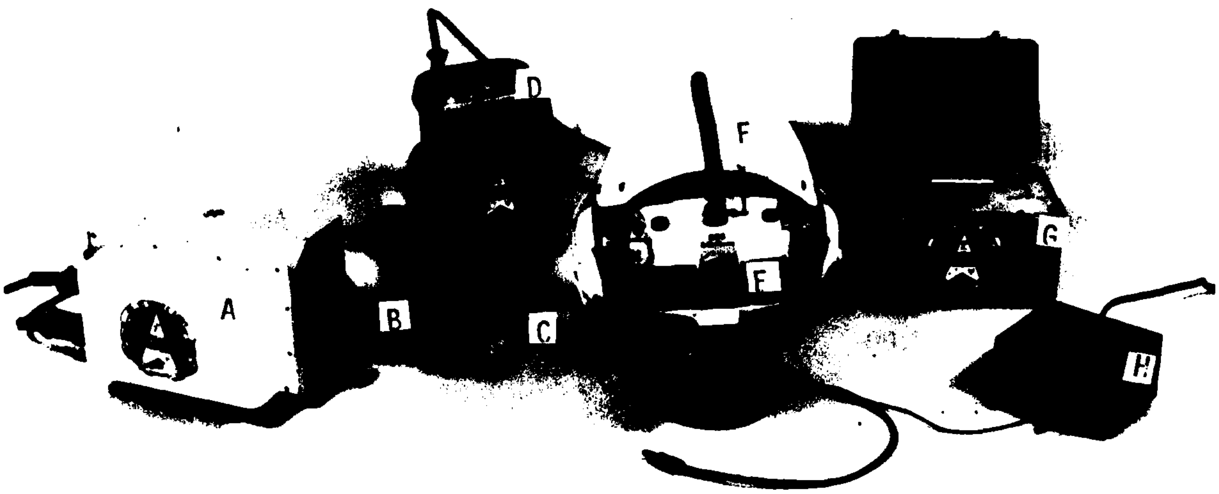


FIGURE 1. NAC Eye Tracker Camera System Arrangement. LOCAM motion picture camera (A), viewfinder (B), optic bundle (C), power source for time code generator (D), NAC eye mark recorder (E), modified PBH-2 tanker's helmet (F), time code generator (G), and NAC eye lamp power supply (H).

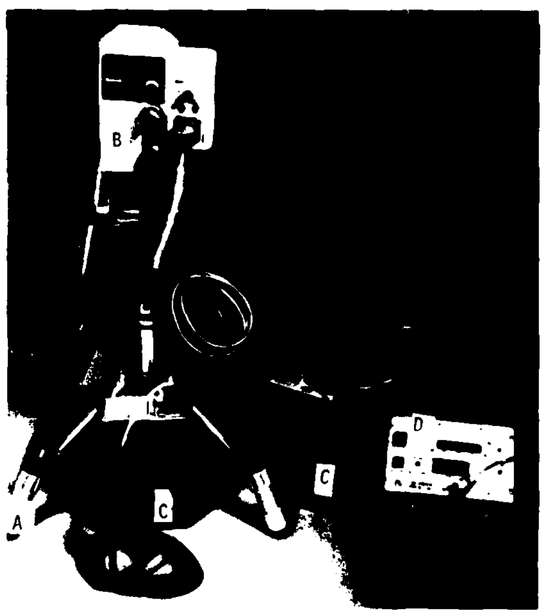


FIGURE 2. Tripod Camera Mount (A) With LOCAM Camera (B), LOCAM Nicad Batteries (C), and Time Code Generator (D).

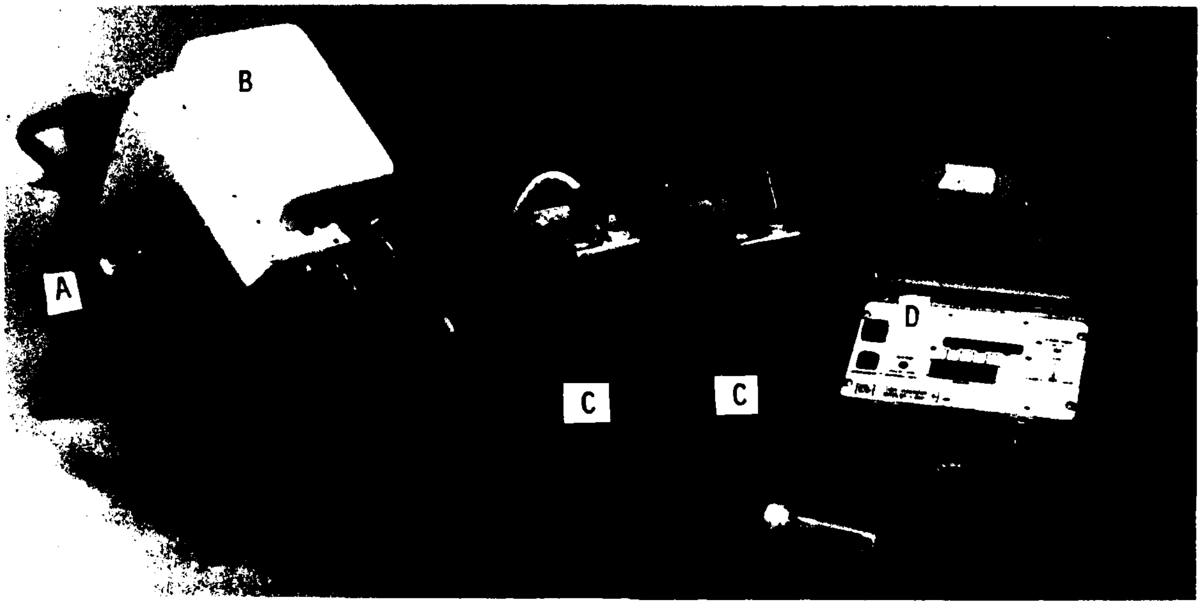


FIGURE 3. Army Lightweight Camera Equipment (ALCE) Pack Frame (A) With LOCAM Camera (B), LOCAM Nicad Batteries (C), and Time Code Generator (D).

NAC Eye Mark Recorder Mask

The NAC optical device utilizes a corneal reflection technique to detect and record eye movement. Structured as a hard plastic mask with adjustable facial pads, the device is secured to the face by nylon straps located over and around the head. An image lens is situated on the facial centerline just above the eyes and references a scene 60 degrees horizontal and 43.5 degrees vertical. A tungsten spot lamp mounted on an extendable rod is attached to the right side of the mask and is adjusted slightly to the right and below the wearer's right eye. When illuminated the lamp's V-shaped reticle can be focused on the cornea, observed through a viewfinder, and then calibrated with xy adjusters to coincide with the eye point of regard. The viewfinder used during the calibration process has been modified to allow the mask optics to be linked to a camera system by a fiber optics bundle. The scene referenced by the image lens of the mask is transmitted through this optic bundle and recorded on 16mm motion picture film. The illuminated reticle is then reflected by a combiner lens and simultaneously superimposed onto the scene being filmed, thus providing a viewable report of the wearer's eye movements.

LOCAM High Speed Motion Picture Camera

A LOCAM Model 51-0002 camera was linked to the NAC mask in order to record eye movements within the visual scene. Data were collected at the rate of 24 frames per second on Kodak EF 434 high speed color film (ASA 640/400 ft X 16). Luminance level readings taken before each period of data collection assured

correct exposure settings. The camera was powered by LOCAM Model 51-0002 DC nicad battery.

Time Code Generator with Event Marker

Time Code Generator Model 13-0007 provides a nine-digit time code formatted in hours, minutes, seconds, and milliseconds. When used in conjunction with the LOCAM camera, this generator consecutively codes each frame of film by superimposing a three-by-three configuration of nine dots along the edge of the film. The presence or absence of each dot enables accurate identification of film frames on the basis of time sequence. Use of the event marker is denoted by the appearance of three additional dots above the nine and results from depressing a hand-held switch. Utilizing event marker capability enabled subjects participating in this experiment to press the switch upon sighting a target; thereby coding film frames containing sighted targets.

Modified PBH-2 Tanker's Helmet

A modified Gentex PBH-2 Tanker's Helmet* provided subjects with safety and communication features, while also stabilizing the NAC mask. Wearing the helmet prevented the mask from shifting due to vibration or head movement and provided a means of securing the optic bundle, which extends over the head from the mask to the camera.

Multiple Extension Tripod and Modified Army Lightweight Camera Equipment Pack Frame

The LOCAM camera was mounted on a multiple extension tripod positioned behind the seat of each aircraft subject, and head movement restrictions imposed by the length of the optic bundle were eliminated by adjusting the tripod legs. Normal mobility of subjects on board surface vessels was retained by fitting them with an Army lightweight pack frame, modified by the addition of a camera mount surface. Bolted to a metal plate affixed to the frame, the camera could be carried by the subject, thus allowing him to perform his normal search behaviors.

PROCEDURE

The USAARL Crew Stress/Workload Team's phase of USCG Winter 1981 Visual/Radar/SLAR Detection Experiment was conducted 3 days each week for a 4-week period. Wednesday was designated as administrative task day. Subjects were selected and given a general briefing on the purpose of the experiment and the procedures which would be used. Components of the NAC Eye Mark Recorder system were demonstrated, movement limitations imposed by the equipment were discussed, and safety procedures were outlined. The biographical data questionnaire, volunteer agreement form, and picture and sound release contained in Appendix A were completed by each subject who then underwent

a Titmus vision examination. Individuals volunteering to participate in the study received an initial fitting of the NAC mask to insure that each had a clear, trackable eye mark and to orient themselves to the sensations associated with wearing it.

Visual data collection was conducted on Thursday and Friday of each week on board both an aircraft and a surface vessel. Search vehicles received a search and rescue exercise (SAREX) message daily and followed the search patterns prescribed in the USCG Winter 1981 Visual/Radar/SLAR Detection Experiment Test Plan (Edwards and Osmer, 1980). The position of each vehicle was monitored by a Microwave Tracking System (MTS)* consisting of a Motorola, Inc., Mini-Ranger III mobile radar tracking system coupled with a Hewlett-Packard 9845B minicomputer (Edwards and Osmer, 1980). Targets anchored along the search routes on visual data collection days were: (1) 16- to 20-foot fiberglass inboard/outboard boats (white or blue), (2) 7-man noncanopy black life rafts, or (3) 4- to 6-man canopy orange life rafts.

When wearing the NAC mask, the flight mechanic was unable to move about the aircraft and perform required safety checks; therefore, this duty was assumed by the radio operator when the flight mechanic was participating as a subject. The duties of surface vessel subjects and all other aircraft crewmen remained unaffected during data collection.

The aircrewmen were called to the cargo area of the helicopter to be fitted with the NAC mask while other team members positioned the camera equipment and tripod. Upon returning to his position, the subject readied himself for search as the final calibration adjustments and camera/mask connections were made. The subject began searching immediately, but the 15-minute period of continuous data collection did not begin until the starting point of a search leg had been reached. Camera sounds were masked by engine noise, thus assuring that the subject was unaware of exactly when his performance was being recorded.

Subjects on board sea vessels were fitted in rooms below deck and then escorted to their respective search positions. Though each subject wore the mask 30 minutes, data collected totaled no more than 15 minutes. The camera was randomly switched on and off (for approximately 5-minute intervals) in an attempt to sufficiently obscure the actual periods of data collection, in the event that the hearing protectors being worn by the subject did not completely eliminate the camera sounds.

During the initial briefing on Wednesday and while being fitted for data collection, subjects were instructed to search according to the procedures they normally use during such missions. In the event of a target sighting, the time code generator switch was to be pressed while verbally reporting the sighting and keeping their eyes "locked" on the target until given the command to continue searching.

Before removing the NAC mask at the end of each session, xy calibration was again checked. Any discrepancies in session start and session end

calibration were recorded on forms to facilitate adjustments during data reduction.

Data Preparation and Analysis

Data reduction equipment. A photographic data reduction system was used to convert the recorded eye movements of each subject to digital form. Elements of the system include a NAC film motion analyzer with projection head,* sonic digitizer graph pen,* and a NOVA 800 computer.* Mounting data films on the projection head allows recorded eye movements to be viewed on the NAC film analyzer screen. Film can be advanced at the rate of 1 to 32 frames per second or automatic sequential film advance at preselected intervals of 1 to 10 frames.

The sonic digitizer graph pen is electronically interfaced to the computer and mechanically interfaced to the film analyzer. Hypersonic impulses generated at the point of the stylus are instrumental in measuring x and y distances. The time required for the sound waves to reach the unit's two linear sensor microphones is converted into distance measurements and presented as coordinates in binary units. This allows interaction with the film and provides the capability to track the eye mark and transform its movements into digital form.

The NOVA 800 computer receives the converted information through an electronic interface and accumulates the data for approximately 1,000 hypersonic impulses. At that point the pen point and film frame number are transferred to NACX, a data handling program in USAARL's Systems 85 digital computer.* Figure 4 shows the NAC photographic data reduction system: a 4025 Tektronix computer* terminal (used in data manipulation after the reduction process has been completed), NOVA 800 computer, sonic digitizer graph pen, and the NAC film motion analyzer with projection head.

FIGURE 4. NAC Photographic Data Reduction System. 4025 Tektronix computer terminal (A), NOVA 800 computer (B), sonic digitizer graph pen (C), and NAC film motion analyzer (D).

The NAC software system is composed of three processing programs--NAC, NACSTAT, and NACPLOT. All are capable of generating output illustrating specific data. NAC provides graphical representation of the computed eye movements and fixations with respect to the scene. A point of fixation (defined as eye movement within the parameters of 1.7 degrees for .16 second) is represented by a circle whose diameter is directly proportional to the duration of the fixation; the width of link lines between areas denotes the frequency with which the eye moved from one to the other; and the actual path of the eye is depicted by a continuous line. As an example, Figure 5 shows the fixation points and link lines of an HH-3F pilot during a 62.5-second film segment. Figure 6 shows the complete path of the eye which yielded the fixation points in Figure 5.

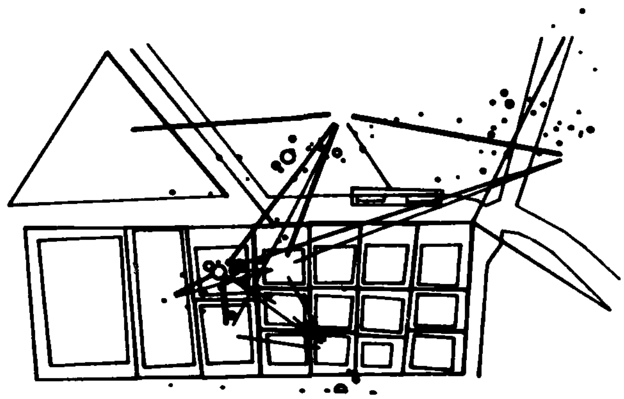


FIGURE 5. Fixation Points and Link Lines of an HH-3F Pilot.

FIGURE 6. Path of the Eye of an HH-3F Pilot.

NACSTAT is designed to derive visual performance/workload measures from the fixation data produced by NAC and to generate a printed report of those measures. Nine values are computed for each defined area of visual contact along with a transition mean, rate, and percent of total time. Table 2 lists and defines those values, and Figures 7 and 8 (p. 19) show representative data printouts of an HH-3F pilot and an HH-3F right door observer, respectively.

TABLE 2

DERIVED OCULOMOTOR PERFORMANCE/WORKLOAD MEASURES

Variable	Description
LKS	Total number of fixations on an area.
LKS%	Percentage of total fixations on an area.
MEAN	Mean dwell time on an area.
MEDI	Median dwell time on an area.
RATE	Scan rate on an area.
% T	Percentage of total film time that the eye was fixated on an area.
CF	Cost factor for an area.
SCMN	Mean time between fixations on an area.
SCMD	Median time between fixations on an area.
TMEA	Average transition time.
TRAT	Transition rate.
T%T	Fraction of total film time that the eye was making transitions.

NACPLOT is programed to draw vertical bar graphs, as shown in Figure 9 (p. 20), which represent the computations derived by NACSTAT. Current visual area variables assigned to appear on the x-axis for statistical comparison are instruments, maneuvers, or subject numbers. In addition, a histogram showing either the distribution of dwell times (fixation durations on an area) or scan time (time between fixation on the same area) can be obtained. Data of HH-3F copilots generated the dwell time histogram in Figure 10 (p. 20) and the scan time histogram in Figure 11 (p. 20).

AREA	LKS #	LKS %	MEAN MS	MED MS	RATE HZ	T %	CF %	SCMN SEC	SCMD SEC
RALT	8	0.7	359.4	458.3	0.9	0.5	0.6	17.2	25.0
BALT	7	0.6	315.5	416.7	0.7	0.4	0.5	17.5	18.8
RMI2	7	0.6	309.5	250.0	0.7	0.4	0.5	18.1	35.0
AH	1	0.1	375.0	333.3	0.1	0.1	0.1	0.0	0.0
RMI	3	0.3	541.7	375.0	0.3	0.3	0.3	0.0	0.0
CLK	3	0.3	722.2	416.7	0.3	0.4+	0.3	38.8	37.5
AS	3	0.3	708.3	458.3	0.3	0.4+	0.3	5.0	3.8
VSI	5	0.4	358.3	208.3	0.5	0.3	0.4	21.9+	40.0
T&B	14	1.2	610.1	437.5	1.5	1.5+	1.4	24.1+	22.5
AS2	1	0.1	333.3	291.7	0.1	0.1	0.1	0.0	0.0
TACH	7	0.6	375.0	458.3	0.7	0.5	0.5	8.8	11.2
OBS	22	1.9	441.3	520.8	2.4	1.7+	1.8	12.2+	12.5
MCAU	4	0.3	312.5	291.7	0.4	0.2	0.3	15.0	17.5
FUEL	1	0.1	500.0	458.3	0.1	0.1	0.1	0.0	0.0
EGST	2	0.2	187.5	208.3	0.2	0.1	0.1	0.0	0.0
WRNG	1	0.1	458.3	416.7	0.1	0.1	0.1	0.0	0.0
RADR	7	0.6	261.9	229.2	0.7	0.3	0.5	14.2+	0.6
LTFT	23	2.0	222.8	163.2	2.5	0.9	1.4	3.8	1.0
RTFT	444	37.8	349.1	421.3	47.5	27.6+	32.7	2.7	3.1
RTSD	387	32.9	307.8	363.0	41.4	21.2	27.1	2.8	1.2
RTCB	97	8.2	267.2	375.0	10.4	4.6	6.4	6.7+	4.7
REST	129	11.0	407.3	513.9	13.8	9.4+	10.2	5.3+	3.1
ZON1	18	1.5	555.6	520.8	1.9	1.8+	1.7	24.1+	22.5
ZON2	8	0.7	515.6	416.7	0.9	0.7+	0.7	16.3+	5.0
ZON3	1150	97.8	373.8	438.6	123.0	76.6+	87.2	3.7+	3.3
TRAN	1176		138.0		125.0	28.9			

FIGURE 7. Example of Data Computed by NACSTAT Program for HH-3F Pilot.

AREA	LKS #	LKS %	MEAN MS	MED MS	RATE HZ	T %	CF %	SCMN SEC	SCMD SEC
1	17	2.8	257.4	162.0	2.5	1.1	1.9	2.3	2.7
2	21	3.5	680.6	472.2	3.0	3.5+	3.5	11.3+	8.8
3	3	0.5	486.1	291.7	0.4	0.4	0.4	2.5	1.3
4	17	2.8	377.5	375.0	2.5	1.6	2.2	8.6+	3.8
5	495	82.4	594.9	707.0	71.8	71.2+	76.8	2.1	2.7
6	28	4.7	379.5	305.6	4.1	2.6+	3.6	8.7	8.8
8	12	2.0	566.0	541.7	1.7	1.6+	1.8	3.8	2.9
9	7	1.2	256.0	250.0	1.0	0.4	0.8	20.3+	16.3
REST	1	0.2	250.0	208.3	0.1	0.1	0.1	0.0	0.0
ZON3	601	100.0	548.9	653.8	87.2	79.8+	89.9	3.0+	2.8
TRAN	601		121.5		87.2	17.7			

FIGURE 8. Example of Data Computed by NACSTAT for Program for HH-3F Right Door/Flight Mechanic.

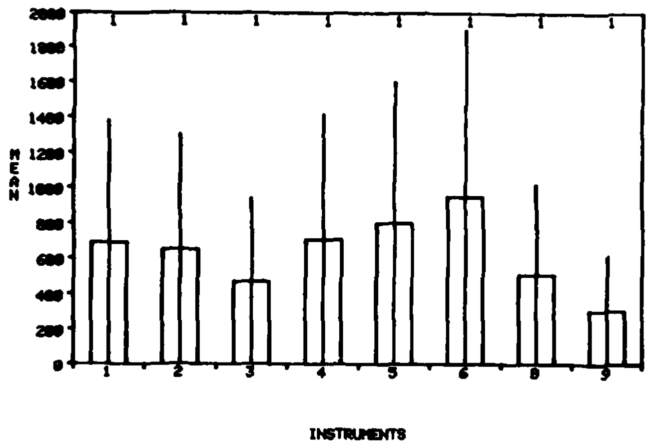


FIGURE 9. Group Mean Dwell Times (In Milliseconds) Across Areas for Right Door/Flight Mechanic HH-3F Observers.

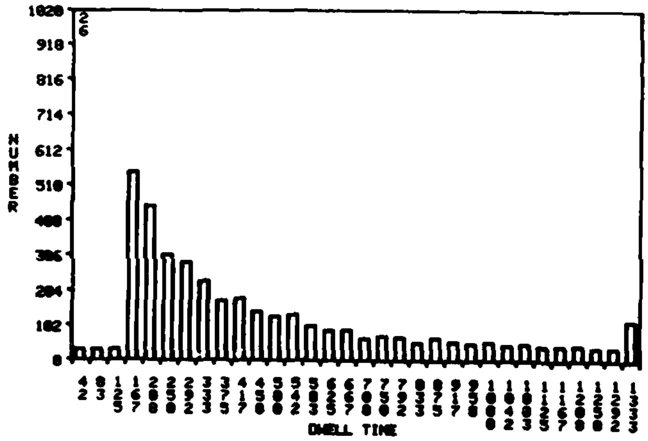


FIGURE 10. Example of Dwell Histogram Computed by NACPLOT for HH-3F Copilots.

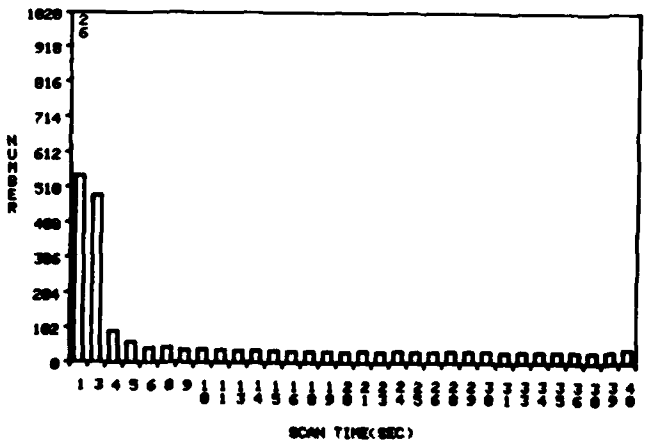


FIGURE 11. Example of Scan Histogram Computed by NACPLOT for HH-3F Copilots.

Data reduction procedures. Converting eye mark movements to digital form began by mounting a subject's film on the projection head of the NAC film motion analyzer and advancing it to the point where search behavior started. A series of xy coordinates were entered into the NOVA 800 by touching the tip of the graph pen to the screen of the NAC analyzer. This procedure established a zero point by which subsequent eye mark movements would be measured. The projector speed was set at four frames per second, and the point of the graph pen was positioned on the screen at the vertex of the eye mark. As the mark moved across the screen, the operator traced its path with the graph pen which simultaneously digitized the information. The eye mark was tracked in segments of 1500 frames.

RESULTS

DESCRIPTIVE SUMMARY OF EYE MOVEMENT DATA BY VEHICLE AND POSITION

USCG HH-3F Rotary Wing Aircraft

Pilots' and copilots' data. Data were collected from four subjects flying as pilots of USCG HH-3F helicopters and five subjects flying as copilots. Table 3 lists group oculomotor activity data within window areas--opposite front window (OFW), direct front window (DFW), side window (SW), and chin bubble (CB)--for pilots and copilots in the categories of number of fixations (Fixations #), percentage of total fixations (Fixation %), and percentage of total search time (Total Time %). Complete group data for all search positions are contained in Appendix C along with a pilot and copilot cockpit diagram and corresponding instrument key. Pilots fixated within the area of the DFW 1,977 times, the equivalent of 51.8 percent of all fixations and 41.8 percent total search/flight time. The area of the SW was fixated on 787 times or 20.6 percent of all fixations for the duration of 13.4 percent total search/flight time. As a group, pilots had a mean total of 3,024 fixations across all window areas which accounts for 79.2 percent of all fixations and 60 percent of total search/flight time.

Copilots fixated within the DFW 1,974 times, the equivalent of 62.3 percent of all fixations and 50.5 percent total search/flight time. The area of the SW was fixated on 415 times or 13.1 percent of all fixations for the duration of 12.1 percent total search/flight time. Copilots as a group had a mean total of 2,617 fixations across all window areas which accounts for 82.6 percent of all fixations and 67.5 percent of total search/flight time.

TABLE 3

HH-3F PILOT AND COPILOT OCULOMOTOR ACTIVITY DATA COMPUTED FOR EACH WINDOW AREA IN THE CATEGORIES OF TOTAL NUMBER OF FIXATIONS, PERCENTAGE OF TOTAL FIXATIONS, AND PERCENTAGE OF TOTAL TIME

WINDOW AREA	FIXATIONS #		FIXATION %		TOTAL TIME %	
	Pilot	Copilot	Pilot	Copilot	Pilot	Copilot
OFW	108	177	2.8	5.6	2.6	3.9
DFW	1977	1974	51.8	62.3	41.8	50.5
SW	787	415	20.6	13.1	13.4	12.1
CB	152	51	4.0	1.6	2.2	1.0
Total	3024	2617	79.2	82.6	60.0	67.5

OFW = opposite front window
DFW = direct front window
SW = side window
CB = chin bubble

Mean dwell time (Mean Dwell) for pilot and copilot fixations within the window areas is shown in Table 4 along with the mean time between returning scans of an area (Scan Mean). The group of pilots had a mean dwell time for fixations in the DFW area of 420.6 milliseconds with a mean scan return time of 2.4 seconds. The SW had a 339.1 milliseconds mean dwell time for fixations with a scan mean of 3.5 seconds. Copilots had a mean dwell time for fixations of 451.4 milliseconds in their DFW with a mean scan return time to that area once every 2.2 seconds. The SW had a 514.3 milliseconds mean dwell time for fixations with a scan mean of 3.8 seconds.

Cost factor (CF) values for pilots and copilots are shown in Table 5. Cost factor is a value developed by Simmons, Lees, and Kimball (1978) which describes the importance or cost of a zone (z) or gauge as perceived by the observer. The CF_z value reflects the percentage of time, scan rate, and dwell time as one value for a specific zone. The theory states that the percentage of total work load required to monitor a gauge can be derived from lapse time and the number of fixations on the gauges.

TABLE 4

HH-3F PILOT AND COPILOT OCULOMOTOR ACTIVITY DATA COMPUTED FOR EACH WINDOW AREA IN THE CATEGORIES OF MEAN DWELL TIME OF FIXATIONS (IN MILLISECONDS) AND MEAN RETURNING SCAN TIME (IN SECONDS)

WINDOW AREA	MEAN DWELL (MS)		SCAN MEAN (SECONDS)	
	Pilot	Copilot	Pilot	Copilot
OFW	485.7	391.9	9.7	5.7
DFW	420.6	451.4	2.4	2.2
SW	339.1	514.3	3.5	3.8
CB	282.3	330.9	6.7	10.2

OFW = opposite front window
DFW = direct front window
SW = side window
CB = chin bubble

TABLE 5

COST FACTOR VALUES COMPUTED FOR HH-3F PILOT AND COPILOT OCULOMOTOR ACTIVITY WITHIN WINDOW AREAS

AREA	COST FACTOR (CF)	
	Pilot	Copilot
OFW	2.7	4.8
DFW	46.8	56.4
SW	17.0	12.6
CB	3.1	1.3

OFW = opposite front window
DFW = direct front window
SW = side window
CB = chin bubble

mula:

$$= \frac{\frac{T}{\Sigma T} + \frac{N}{\Sigma N}}{2}$$

Dwell time in seconds within the zone.
Number of fixations within the zone.

hest workload percentages (CF) for pilots were in the DFW (46.8 d the SW (17.0 percent) areas. The highest CF percentages for re DFW, 56.4 percent, and SW, 12.6 percent.

ight door/flight mechanic (RD/FM) and left window/radio operator a. Data was collected from six right door/flight mechanics and window/radio operators. The unobstructed scene viewed by individ- h these positions as well as on board surface vessels was divided square grid pattern during the scoring process to facilitate of their areas of search concentration. Areas were numbered y top to bottom, right to left as shown in Figure 12. Table 6 and LW/RO group data for search areas 1 through 9 in the of total number of fixations, percentage of total fixations, and of total search time. RD/FM observers concentrated their search area 5 which had 2,220 fixations or the equivalent of 62.9 percent tions and 62.4 percent of total search time. Area 1 had the second ber of fixations (551), which equals 15.6 percent of all fixations rcent of total search. Fixations within areas 2, 4, and 6 ranged 235 for a total of 19.2 percent of all fixations and 18.2 percent arch time. Areas 3, 8, and 9 had only 72 fixations (2 percent) accounting for 1.2 percent total search time while area 7, the hand corner, had no fixations.

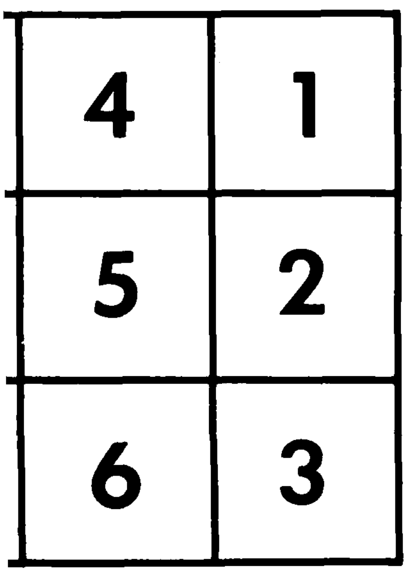


FIGURE 12. Grid Pattern Used During Data Scoring Process to Facilitate Discussion of Search Concentration.

TABLE 6

HH-3F RIGHT DOOR/FLIGHT MECHANIC AND LEFT WINDOW/RADIO OPERATOR OCULOMOTOR ACTIVITY DATA COMPUTED FOR EACH SEARCH AREA IN THE CATEGORIES OF TOTAL NUMBER OF FIXATIONS, PERCENTAGE OF TOTAL FIXATIONS, AND PERCENTAGE OF TOTAL TIME

SEARCH AREA	FIXATIONS #		FIXATION %		TOTAL TIME %	
	RD/FM	LW/RO	RD/FM	LW/RO	RD/FM	LW/RO
1	551	189	15.6	9.9	13.3	5.9
2	235	264	6.7	13.8	5.4	18.5
3	28	-	0.8	-	0.5	-
4	227	171	6.4	9.0	5.6	6.8
5	2220	1247	62.9	65.3	62.4	64.9
6	216	6	6.1	0.3	7.2	0.2
7	-	-	-	-	-	-
8	36	29	1.0	1.5	0.6	1.0
9	8	-	0.2	-	0.1	-
Total	3521	1906	99.7	99.8	95.1	97.3

RD/FM = right door/flight mechanic
LW/RO = left window/radio operator

LW/RO observers also concentrated their search activity in area 5 which had 1,247 fixations or the equivalent of 65.3 percent of all fixations and 64.9 percent of total search time. Area 2 had the second highest number of fixations (264), which equals 13.8 percent of all fixations and 18.5 percent of total search. Fixations within areas 1 and 4 ranged from 171 to 189 for a total of 18.9 percent of all fixations and 12.7 percent of total search time. Areas 6 and 8 had only 35 fixations (1.8 percent) among them accounting for 1.2 percent of total search time, while areas 3, 7, and 9 had no fixations.

Mean dwell times for fixations (Mean Dwell) and mean time between returning scans of an area (Scan Mean) are shown for RD/FM and LW/RO observers in Table 7. The highest mean dwell times for RD/FM fixations occurred in area 6 (949.8 milliseconds), which had a return scan rate of once every 6 seconds. Area 5 had the second highest mean dwell time (800.7 milliseconds) and also the shortest return scan figure (2.5 seconds). Area 7 had no fixations.

LW/RO had a mean fixation dwell time within area 2 of 1,116.5 milliseconds and a return scan rate of once every 3.4 seconds. The second highest mean dwell time occurred in area 5 (831.1 milliseconds) which also had the shortest return to scan figure (2.7 seconds). Areas 3, 7, and 9 had no fixations.

TABLE 7

HH-3F RIGHT DOOR/FLIGHT MECHANIC AND LEFT WINDOW/RADIO OPERATOR OCULOMOTOR ACTIVITY DATA COMPUTED FOR EACH SEARCH AREA IN THE CATEGORIES OF MEAN DWELL TIME OF FIXATIONS (IN MILLISECONDS) AND MEAN RETURNING SCAN TIME (IN SECONDS)

SEARCH AREA	MEAN DWELL (MS)		SCAN MEAN (SECONDS)	
	RD/FM	LW/RO	RD/FM	LW/RO
1	689.3	502.0	2.6	3.7
2	650.4	1116.5	5.5	3.4
3	470.2	-	12.0	-
4	707.6	630.4	3.6	4.8
5	800.7	831.1	2.5	2.7
6	949.8	465.3	6.0	30.0
7	-	-	-	-
8	509.3	566.1	8.0	8.6
9	307.3	-	20.3	-

RD/FM = right door/flight mechanic
LW/RO = left window/radio operator

The cost factor (CF) values in Table 8 show that RD/FM (62.7 percent) and LW/RO (65.1 percent) observers were approximately equal in their oculomotor activity within area 5. Area 1 (14.5 percent) had the second highest CF percentage of RD/FM observers. Percentages in areas 2, 4, and 6 ranged from 6.0 to 6.7 and percentages in areas 3, 8, and 9 ranged from 0.2 to 0.8. There were no fixations within area 7. Area 2 (16.1) had the second highest CF percentage of LW/RO observers. Percentages in areas 1 and 4 were 7.9 with the percentages in areas 6 and 8 being 0.2 and 1.3. There were no fixations in areas 3, 7, and 9.

USCG Surface Vessels

82-foot and 210-foot (starboard and port sides) cutters observer data. Data were collected from 9 individuals on board 82-foot cutters and from 15 individuals on board 210-foot cutters--10 from the starboard side and 5 from the port side. Table 9 (p. 28) shows statistical values by area for each of these three positions in the categories of total number of fixations, percentage of total fixations, and percentage of total search time.

TABLE 8

COST FACTOR VALUES COMPUTED FOR HH-3F RIGHT DOOR/FLIGHT MECHANIC AND LEFT WINDOW/RADIO OPERATOR OCULOMOTOR ACTIVITY WITHIN SEARCH AREAS

SEARCH AREA	COST FACTOR (CF)	
	RD/FM	LW/RO
1	14.5	7.9
2	6.0	16.1
3	0.6	-
4	6.0	7.9
5	62.7	65.1
6	6.7	0.2
7	-	-
8	0.8	1.3
9	0.2	-

RD/FM = right door/flight mechanic
LW/RO = left window/radio operator

Observers on the 82-foot cutters concentrated their search activity in area 5 which had 1,186 fixations or 46.4 percent of all fixations. Percentage of search time spent in this area was 47.3. Area 2 had 514 fixations which accounted for 20.1 percent of all fixations and 17.0 percent of total search time. Fixations in areas 1, 3, 4, 6, and 8 ranged from 47 in area 8 to 246 in area 6. The combined percentage of fixations in these areas totaled 32.5 percent, and the amount of search time spent within the areas was 33.4 percent. There were no fixations in areas 7 and 9.

Observers on the starboard side of the 210-foot cutter spent 84.8 percent of total search time in areas 2 and 5. The number of fixations, 1,376 and 1,428, represented 86.6 percent of all fixations and were almost equally divided between the two areas. Fixations in areas 1, 3, 4, 6, 7, and 8 ranged from 7 in area 7 to 215 in area 1 which equals only 12.7 percent of all fixations and 13.7 percent of total search time. Area 9, the bottom left-hand corner, had no fixations.

The port side observers on the 210-foot cutter fixated within area 5, 710 times which represents 51.0 percent of all fixations and accounts for 37.9 percent of total search time. Area 2 with 428 fixations had 30.7 percent of all fixations and 22.2 percent of total search time. Fixations in areas 1, 3, 4, and 6 ranged from 42 in area 6 to 101 in area 1 for a combined total of 17.2 percent of all fixations and 38.7 percent of total search time. There were no fixations in areas 7, 8, and 9.

TABLE 9

US COAST GUARD CUTTER OBSERVER OCULOMOTOR ACTIVITY DATA COMPUTED FOR EACH SEARCH AREA IN THE CATEGORIES OF TOTAL NUMBER OF FIXATIONS, PERCENTAGE OF TOTAL FIXATIONS, AND PERCENTAGE OF TOTAL TIME

SEARCH AREA	FIXATIONS (#)			FIXATION (%)			TOTAL TIME (%)	
	82-Foot Cutter	210-Foot Cutter (Starboard)	210-Foot Cutter (Port)	82-Foot Cutter	210-Foot Cutter (Starboard)	210-Foot Cutter (Port)	82-Foot Cutter	210-Foot Cutter (Starboard)	210-Foot Cutter (Port)
1	130	215	101	5.1	6.6	7.3	3.8	7.3	26.5
2	514	1376	428	20.1	42.5	30.7	17.0	31.8	22.2
3	177	21	43	6.9	0.6	3.1	8.6	0.1	1.3
4	233	133	53	9.1	4.1	3.8	8.5	4.8	9.8
5	1186	1428	710	46.4	44.1	51.0	47.3	53.0	37.9
6	246	9	42	9.6	0.3	3.0	11.0	0.1	1.1
7	-	7	-	-	0.2	-	-	0.2	-
8	47	30	-	1.8	0.9	-	1.5	1.2	-
9	-	-	-	-	-	-	-	-	-
TOTAL	2533	3219	1377	99.0	99.3	98.9	97.7	98.5	98.8

Table 10 reports the mean dwell time for fixations in each of the nine areas along with the return scan means. The highest fixation dwell time for observers on the 82-foot cutters occurred in area 3 (1,739.6 milliseconds). The return scan mean for this area was once every 6.9 seconds. The second highest mean dwell time was 1,616.0 milliseconds in area 6, which had a return scan mean of 5.5 seconds. There were no fixations in areas 7 and 9.

TABLE 10

US COAST GUARD CUTTER OBSERVER OCULOMOTOR ACTIVITY DATA COMPUTED FOR EACH SEARCH AREA IN THE CATEGORIES OF MEAN DWELL TIME OF FIXATIONS (IN MILLISECONDS) AND MEAN RETURNING SCAN TIME (IN SECONDS)

SEARCH AREA	MEAN DWELL (MS)			SCAN MEAN (SECONDS)		
	82-Foot Cutter	210-Foot Starboard	210-Foot Port	82-Foot Cutter	210-Foot Starboard	210-Foot Port
1	1045.5	1726.0	9108.1	3.5	4.3	7.4
2	1190.3	1168.0	1801.2	4.6	4.1	6.0
3	1739.6	333.3	1038.8	6.9	8.8	5.2
4	1319.9	1820.5	6413.5	3.8	6.0	10.5
5	1434.0	1873.1	1855.0	3.9	4.5	4.0
6	1616.0	476.9	884.9	5.5	40.0	8.4
7	-	1547.6	-	-	18.5	-
8	1112.6	1972.2	-	6.8	5.0	-
9	-	-	-	-	-	-

Mean fixation dwell times of starboard side observers on the 210-foot cutter were 1,972.2 in area 8; 1,873.1 in area 5; and 1,820.5 in area 4. Return scan rates for these areas ranged from 4.5 to 6.0 seconds. There were no fixations in area 9. Port side observers on the 210-foot cutter had mean fixation dwell times of 9,108.1 milliseconds in area 1 with a return scan rate of 7.4 seconds. Area 4 had mean dwell times of 6,413.5 milliseconds and a return scan rate of 10.5 seconds. There were no fixations in areas 7, 8, and 9. All three surface vessel positions had their highest cost factor (CF) values (46.8, 48.5, and 44.5) in area 5 and their second highest CF value (18.6, 37.2, and 26.5) in area 2 (Table 11).

TABLE 11

COST FACTOR VALUES COMPUTED FOR US COAST GUARD CUTTER OBSERVER OCULOMOTOR ACTIVITY WITHIN SEARCH AREAS

SEARCH AREA	COST FACTOR (CF)		
	82-Foot Cutter	210-Foot Starboard	210-Foot Port
1	4.4	7.0	16.9
2	18.6	37.2	26.5
3	7.7	0.4	2.2
4	8.8	4.5	6.8
5	46.8	48.5	44.5
6	10.3	0.2	2.0
7	-	0.2	-
8	1.6	1.0	-
9	-	-	-

Comparison Across All Positions

Table 12 reports the total time percentages for each search position in the categories of instruments, search area, rest (all areas other than instruments or windows; i.e., panel space between instruments), and transition (time spent moving eye from one fixation to another). Pilots spent 13.2 percent of their search time looking at their instruments, 60.0 percent of their time fixating in window areas, 6.7 percent of their time looking at areas defined as rest and 20.1 percent of their time transitioning from one fixation to another. Copilots concentrated their oculomotor activity in search areas (67.5 percent) while spending only 6.5 percent of their time looking at their instruments, 4.6 percent in rest areas, and 21.4 percent engaged in transition.

Right door observers fixated within search areas 95.1 percent of total search time and spent only 0.2 percent of their time fixating on rest areas and 4.7 percent of their time transitioning from fixation to fixation. Left window observers fixated within search areas 97.3 percent of total search time and spent only 0.1 percent of their time fixating on rest areas and 2.6 percent of their time transitioning from fixation to fixation.

TABLE 12

PERCENTAGE OF TOTAL TIME OBSERVERS AT EACH SEARCH POSITION SPENT ENGAGING IN OCULOMOTOR ACTIVITY WITHIN THE AREAS OF INSTRUMENTS, SEARCH AREAS, AND REST AREAS AND TRANSITIONING FROM ONE FIXATION TO ANOTHER

AREA	TOTAL TIME (%)						
	Pilot	Copilot	RD/FM	LW/RO	82-Foot Cutter	210-Foot Cutter (Starboard)	210-Foot Cutter (Port)
Instruments	13.2	6.5	-	-	-	-	-
Search	60.0	67.5	95.1	97.3	97.7	98.5	98.8
Rest	6.7	4.6	0.2	0.1	0.8	0.6	0.6
Transition	20.1	21.4	4.7	2.6	1.5	0.9	0.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

RD/FM = right door/flight mechanic
LW/RO = left window/radio operator

Observers on the 82-foot cutters spent 97.7 percent of their time fixating within search areas, 0.8 percent of their time in rest areas, and 1.5 percent engaging in transition activity. Starboard side observers on the 210-foot cutter fixated within search areas 98.5 percent of total search time. The percentages for rest and transition were 0.6 percent and 0.9 percent. Port side observers on the 210-foot cutter spent 98.8 percent of their time fixating within search areas and 0.6 percent in rest and transition activity.

Experienced Versus Novice Lookout/Scanner Data

Oculomotor activity data computed across search areas for selected individuals designated as experienced and novice observers is presented in Table 13. One observer with a high search and rescue experience level and one observer with a low search and rescue experience level were chosen from the four positions of pilot/copilot, right door/left window, 82-foot cutter, and 210-foot cutter. Means were computed for data in the categories of number of fixations, percentage of total fixations, percentage of total time, fixation dwell time, and return scan rate. Rest and transition figures are also presented.

TABLE 13

OCULOMOTOR ACTIVITY DATA COMPUTED ACROSS SEARCH AREAS FOR EXPERIENCED AND NOVICE OBSERVERS (BASED ON YEARS OF SEARCH EXPERIENCE)

CATEGORY (MEAN)	HH-3F PILOT/COPILOT		HH-3F RIGHT DOOR/ LEFT WINDOW		82-FOOT CUTTER		210-FOOT CUTTER	
	Experienced (13 yrs)	Novice (5 yrs)	Experienced (6 yrs)	Novice (1.5 yrs)	Experienced (6 yrs)	Novice (0.25 yrs)	Experienced (14 yrs)	Novice (0.0 yrs)
Fixations #	145.50	114.75	149.75	62.71	44.20	46.20	29.50	62.00
Fixation %	22.53	19.00	25.03	15.06	19.98	19.74	25.03	20.00
Total Time %	20.83	15.05	24.48	13.69	19.22	19.18	24.95	19.76
Fixation Dwell (ms)	462.68	409.43	851.08	753.21	783.44	930.04	5525.00	1023.16
Scan Rate (Seconds)	2.88	7.13	1.53	6.17	3.92	5.68	12.03	6.08
Rest	2.30	10.80	-	1.00	-	1.10	-	-
Transition	10.60	22.50	2.10	3.10	3.90	3.00	0.20	1.30

Mean number of fixations reported in the pilot/copilot position were 145.50 for experienced and 114.75 for novice. The mean fixation percentage per area for the experienced observer was 22.53 percent and 19 percent for the novice observer. Mean percentage of total time per area was 20.83 percent for the experienced observer and 15.05 percent for the novice observer. Mean fixation dwell time for the experienced observer was 462.68 milliseconds and 409.43 milliseconds for the novice observer. The mean scan rate per area was 2.88 seconds for experienced and 7.13 seconds for novice. The experienced observer had a rest percentage of 2.3 percent and a transition percentage of 10.6 percent while the novice observer had a rest percentage of 10.8 percent and a transition percentage of 22.5 percent.

Mean number of fixations reported in the right door/left window position were 149.75 for experienced and 62.71 for novice. The mean fixation percentage per area for the experienced observer was 25.03 percent and 15.06 percent for the novice observer. Mean percentage of total time per area was 24.48 percent for the experienced observer and 13.69 percent for the novice observer. Mean fixation dwell time for the experienced observer was 851.08 milliseconds and 753.21 milliseconds for the novice observer. The mean scan rate per area was 1.53 seconds for experienced and 6.17 seconds for novice. The experienced observer had a rest percentage of 0 percent and a transition percentage of 2.1 percent while the novice observer had a rest percentage of 1 percent and a transition percentage of 3.1 percent.

Mean number of fixations reported in the 82-foot cutter position were 44.2 for experienced and 46.2 for novice. The mean fixation percentage per area for the experienced observer was 19.98 percent and 19.74 percent for the novice observer. Mean percentage of total time per area was 19.22 percent for the experienced observer and 19.18 percent for the novice observer. Mean fixation dwell time for the experienced observer was 783.44 milliseconds and 930.04 milliseconds for the novice observer. The mean scan rate per area was 3.92 seconds for experienced and 5.68 seconds for novice. The experienced observer had a rest percentage of 0 percent and a transition percentage of 3.9 percent while the novice observer had a rest percentage of 1.1 percent and a transition percentage of 3 percent.

Mean number of fixations reported in the 210-foot cutter position were 29.5 for experienced and 62 for novice. The mean fixation percentage per area for the experienced observer was 25.03 percent and 20 percent for the novice observer. Mean percentage of total time per area was 24.95 percent for the experienced observer and 19.76 percent for the novice observer. Mean fixation dwell time for the experienced observers was 5,525 milliseconds and 1,023.16 milliseconds for the novice observer. The mean scan rate per area was 12.03 seconds for experienced and 6.08 seconds for novice. The experienced observer had a rest percentage of 0 percent and a transition percentage of 0.2 percent while the novice observer had a rest percentage of 0 percent and a transition percentage of 1.3 percent.

DISCUSSION

The overall goal of this initial study on oculomotor activity, as stated in the Winter 1981 Visual/Radar/SLAR Detection Experiment Test Plan (Edwards and Osmer, 1980) was to determine the rate of eye movements in lookout/scanner performance. The four specific objectives addressed by USAARL's NAC eye movement research methods were:

1. Determine the portion of time that lookouts/scanners spend engaging in visual search activity.

2. Determine the patterns of eye movement, eye fixation, and head movement used by experienced versus novice lookouts/scanners.

3. Investigate eye movements and lookout response just prior to target detection.

4. Correlate scanning patterns with target detections as a measure of lookout effectiveness.

Data presented in the Results section is directly related to objectives 1 and 2; however, equipment malfunctions of the time code generator and event marker resulted in an inability to compute meaningful data regarding objectives 3 and 4. Both the data presented in the Results section and subjective researchers' evaluations of the data films will be cited while discussing the original objectives of determining the duration of observers' visual search activity and identifying the oculomotor behavior of experienced versus novice observers. In addition the information will be used to expound upon the following investigative observations, made a posteriori:

1. Absence of systematic scan patterns as prescribed in *US Coast Guard Shipboard Lookout Manual* (CG-414).

2. "Eye-lock" phenomena within the search area.

3. Search paths dictated by obstructions or environmental configurations within the field of view.

4. Concentration of search activity on or near the horizon without regard to environmental conditions or target type.

EQUIPMENT RELATED DEFICIENCIES RESULTING IN LOSS OF DATA

The purpose of the time code generator and event marker was to code film frames containing a detected target. Without the code to identify a target, it is impossible to locate it, due to the quality of film resolution coupled

with its color and small size against a water background. Coding the film was a function of an internal component known as an LED (light emitting diode). At an unknown point during data collection, the LED circuit malfunctioned and its capability to code film frames was destroyed. Continuous monitoring of the functioning external display gave no indication that an internal malfunction had occurred; therefore, though all equipment was disassembled for cleaning and repairs after each use, the disabled LED was not discovered until data reduction had begun and the absence of the code was questioned.

A second equipment related problem was discovered during the film scoring process. By tracking two fixed points of reference, as well as the eye mark itself, meaningful data regarding head movement can be obtained. Having dealt only with pilot and copilot positions, the need to provide artificial fixed points for the other positions was not realized. Regardless of movement made by individuals in the cockpit controlling the aircraft, fixed points of reference are in view, for example the instruments or windscreen. After developing the films, it was found that positions taken by the flight mechanic, radio operator, and surface vessel observers completely eliminated the presence of any fixed points in the scene. Leaning forward toward the right door or left window in the HH-3F shifted the vertex of the NAC camera lens angle resulting in the door and window frames being blocked from view. Much the same problem occurred on the 82-foot WPB. From the observer position, the only reference point was the back corner of the cabin. Those subjects who searched laterally and to the stern of the boat provided no fixed points in the scene. Observers on the 210-foot WMEC always had the flying bridge rail in view. Unfortunately, their mobility in the totally open space on deck allowed them to search a full 180 degrees, if not more, thus diminishing the likelihood of remaining in range of the original tracking points. The combination of a disabled LED and the absence of fixed tracking points nullified our ability to assess head movement differences, to quantify eye movements just prior to target detection, and to accurately correlate scanning patterns with target detection rates.

DURATION OF VISUAL SEARCH ACTIVITY

Table 12 summarized the portion of time that observers at each position spent fixating within search and rest areas and transitioning from one fixation to another. All positions with the exception of pilot and copilot had comparable fixations within search areas, more than 95 percent of the total search time, and had a range of rest fixations from 0.1 to 0.8. Transition data for right door/flight mechanic (4.7 percent) and left window/radio operator (2.6 percent) were higher than the rates for observers on the 82-foot cutter (1.5 percent), the 210-foot cutter starboard (0.9 percent), and the 210-foot cutter port (0.6 percent), creating an almost clear break in transition activity between the two search vehicles. Search activity percentages among pilots (60.0) and copilots (67.5) were lower than the other positions, and their transition rates higher (20.1 percent and 21.4 percent) due to the additional task of flying the aircraft.

"EYE LOCK" PHENOMENON AND THE ABSENCE OF SYSTEMATIC SCAN PATTERNS

Though observers on board surface vessels and in the noncockpit areas of the HH-3F spent almost 100 percent of their search time fixating within search areas, there is some question as to whether they were actively searching. The initial review of the data films revealed that observers were not using the systematic scan patterns prescribed in *US Coast Guard Shipboard Lookout Manual* (CG-414). The statistical values later computed from the data films confirmed that observers were confining their search activity to one or two sections of the total area. Fixations per section for cutter observers and noncockpit HH-3F observers are shown in Tables 6 and 9. Without exception, area 5, the center section, received the highest number of fixations; and the fixation percentages for this area ranged from 44.1 percent to 51 percent on the cutters and 62.9 percent to 65.3 percent in the noncockpit areas of the HH-3F. Pilots and copilots (Table 3) also concentrated their search activity in a single area, the direct front window. More than 50 percent of all fixations occurred within this area. Fixations within the three remaining window areas ranged from 108 (2.8 percent) to 787 (20.6 percent) at the pilot position and 51 (1.6 percent) to 415 (13.1 percent) at the copilot position.

These numbers support the statement that systematic scanning coverage of search areas is not occurring. Area 7, the upper left section, remained unsearched by observers in four out of five search positions, as did area 9, the lower left section. Area 8, the middle left section, was ignored by port side observers on the 210-foot cutter; and area 3, the lower right corner, was not searched by HH-3F left window/radio operators. The stippled portion of each area in Figure 13 represents the mean percentage of fixations per area computed across all search positions (with the exception of pilots and copilots). This graphically illustrates that search activity was confined primarily to areas 5 and 2. Due to a phenomenon termed "eye lock", however, it is unclear whether those fixations constitute search behavior.

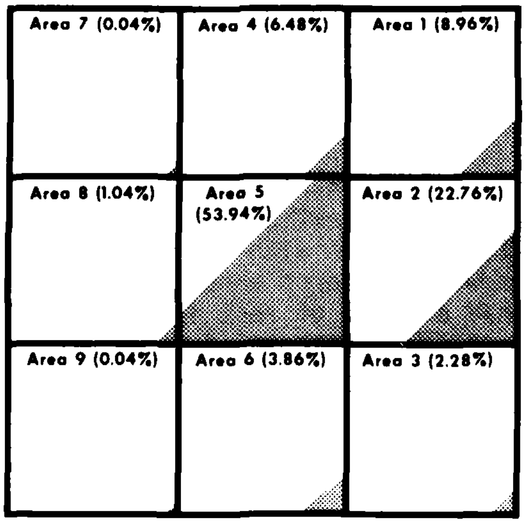


FIGURE 13. Illustration of Percentage of Fixations Per Area Across All Observers (With the Exception of Pilots and Copilots).

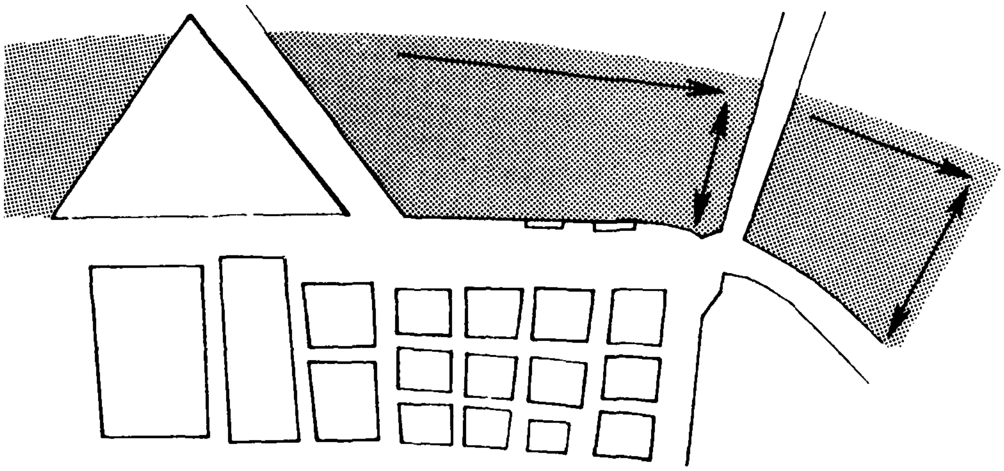
"Eye lock" has been defined as search behavior utilizing small or no saccadic eye movements while relying on movement of the search vehicle to dictate the scan path. It was observed visually on the data films and then corroborated by the mean fixation dwell times and the return scan rates reported in Tables 7 and 10. The resulting path appears as a straight line with little or no deviation. Comparing pilot and copilot mean dwell times in Table 4 with those of the noncockpit HH-3F observers in Table 7 and the cutter observers in Table 10, a trend towards higher dwell times can be seen in the direction of pilot/copilot, right door/left window, and cutter. The pilot/copilot group had mean fixation dwell times ranging from 282.3 milliseconds to 514.2 milliseconds and return scan rates of 2.2 seconds to 10.2 seconds. The right door/left window group had mean fixation dwell times ranging from 307.3 milliseconds to 1,116.5 milliseconds and return scan rates of 2.6 seconds to 20.3 seconds. The observers on board cutters had mean fixation dwell times ranging from 333.3 milliseconds to 9,108.1 milliseconds and return scan rates of 3.5 seconds to 40.0 seconds. The longer the mean dwell times, the fewer the fixations and, thereby, the smaller the area which can be searched. The smaller the return scan mean, the higher the number of fixations within the area.

Does covering an area while engaging in "eye lock" constitute searching? At the present time that question cannot be answered. When targets were clearly visible in the data films, some were detected and others remained undetected during periods of stationary oculomotor activity. Upon reviewing the data films, it was concluded that current USAARL technology is incapable of distinguishing between no eye movement search and a daydream-like gaze.

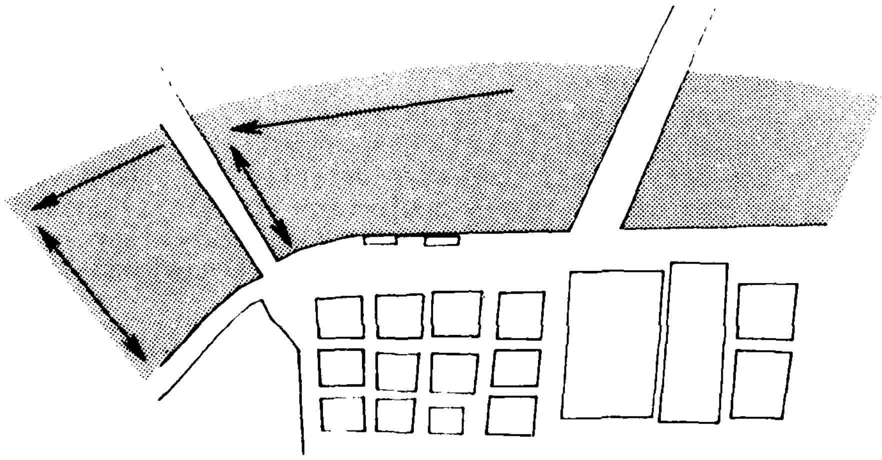
SEARCH PATHS ARE DICTATED BY ENVIRONMENT CONFIGURATIONS

One of several observations made while subjectively evaluating the contents of the data films was that lookouts/scanners tend to search along obstructions or environmental configurations within their field of view. The majority of horizontal search sweeps made by observers at each aircraft and surface vessel position were on or near the horizon. Vertical sweeps made by individuals in the cockpit of the HH-3F were along the window frames within their fields of view. The arrows in Figure 14 show the scan direction of oculomotor movement made by HH-3F pilots, and the arrows in Figure 15 show the scan direction of oculomotor movements made by HH-3F copilots. The pattern was to make a parallel sweep of the horizon and a vertical sweep of the frame of the front window, proceed to the next window, and then the next with the same motion. Most returned to the front windows to repeat the process, though some simply reversed the scan direction.

Aircraft observers at the right door position made only one vertical sweep, as did the left window observers. Both usually searched to the direction of their left side; therefore, the right door observers tended to search laterally and toward the front of the aircraft while the left window observers searched laterally and to the rear. Figure 16 illustrates the pattern most frequently used by right door and left window observers.



RE 14. HH-3F Pilot Cockpit Windows With Scan Direction Arrows.



RE 15. HH-3F Copilot Cockpit Windows With Scan Direction Arrows.

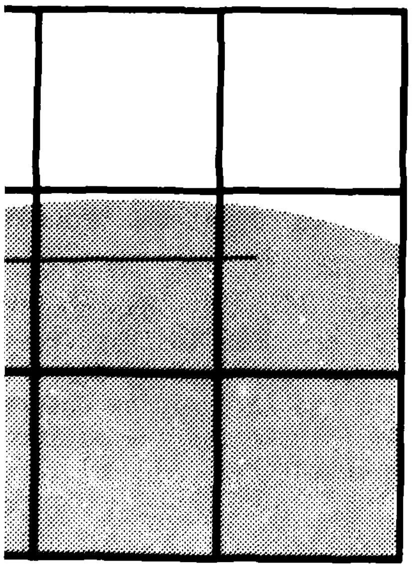


FIGURE 16. Representation of HH-3F Right Door and Left Window Showing Scan Direction Arrows.

Observers on board the 82-foot WPB had only the horizon as an environmental guide, making eye-lock more prevalent and noticeable. Starboard and port observers on the 210-foot WMEC searched along the rail. When actively scanning, individuals on both platforms made a horizontal sweep just below the horizon, returned to the center point of that sweep, and then quickly made two diagonal sweeps as shown in Figure 17.

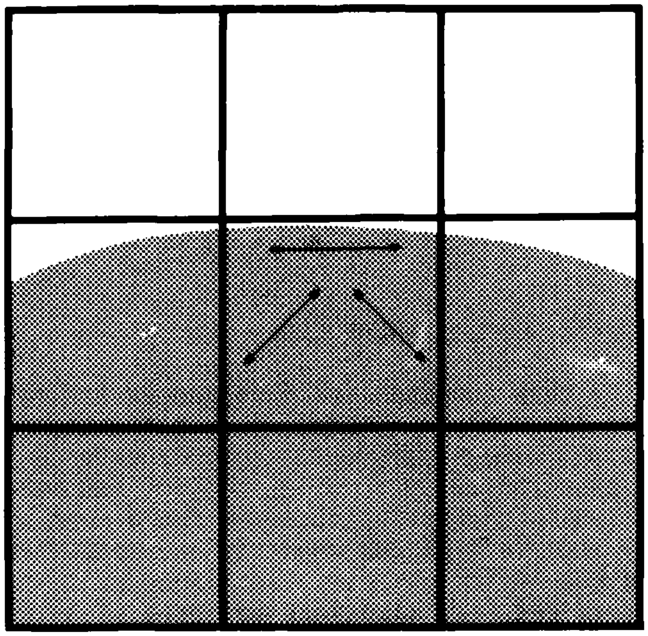


FIGURE 17. Representation of 82-Foot WPB and 210-Foot WMEC Observer Positions Showing Scan Direction Arrows.

Though there was a wide variety of scanning techniques used by participants of this study, the previously mentioned patterns consistently appeared. It should be noted that search strategies differed according to platform and position, but that following obstructions or environment configurations as a guide for search patterns was the underlying tendency for all individuals.

SEARCH ACTIVITY IS CONCENTRATED ON OR NEAR THE HORIZON

The horizontal scan lines shown in Figures 15, 16, and 17 illustrate another tendency of the majority of observers. Search activity was confined almost exclusively in the area from the horizon, midway to the search vehicle, primarily at a point two-thirds of the way from the vehicle to the horizon. In addition to the obvious result of leaving a wide band of the ocean's surface unsearched, there is some question as to whether targets can be seen at that distance. The size and color of the target along with environmental factors affect the probability of its detection. Under optimum conditions the Coast Guard reports that for a small orange raft at a distance of 3

nautical miles or greater only one in seven can be seen from a surface vessel and only one in six from a helicopter at an altitude of 500 feet (Edwards, et al. 1981). In our current study, subjects were searching for the same targets under optimum to poor weather conditions; however, subjective evaluation of the data films shows that the majority of observers maintained the same eye position, on or near the horizon. The Height of Eye Vs. Horizon Range Chart contained in the *American Practical Navigator; Being an Epitome of Navigation* (1976) states that the horizon line from an 82-foot cutter (25-foot eye level) is 5.7 nautical miles away. From a 210-foot cutter (46-foot eye level), it is 7.8 nautical miles away; and the distance from an HH-3F at an altitude of 500 feet measures approximately 25.6 nautical miles. If a small orange raft is undetectable at a distance greater than 3 nautical miles, it is unlikely that targets of the size and color used during this study are detectable within areas near the horizon in anything less than optimum conditions.

EXPERIENCED VERSUS NOVICE LOOKOUTS/SCANNERS

Oculomotor activity data computed for experienced and novice observers were reported in Table 13. Only two categories, percentage of fixation and percentage of total time, were consistent across experience level and search position. An experienced HH-3F pilot/copilot had mean fixations per area of 22.53 percent while the novice observer had a mean of 19.0 percent. The experienced right door/left window observer had mean fixations per area of 25.03 percent, and the novice observer had a mean of 15.06 percent. The 82-foot cutter observers had mean fixations per area of 19.98 percent for experienced and 19.74 percent for novice. The 210-foot cutter observers had mean fixations per area of 25.03 percent for experienced and 20.00 for novice observers.

An experienced HH-3F pilot/copilot had percentages of total time figures of 20.83 percent while the novice observer had a time of 15.05. The experienced right door/left window observers had percentage of time per area of 24.48 percent, and the novice observer had a mean of 13.69 percent. The 82-foot cutter observers had percentage of time figures of 19.22 percent for experienced and 19.18 for novice. The 210-foot cutter observers had percentage of total time figures of 24.95 percent for experienced observers and 19.76 for novice observers. Though the percentage of mean fixation and the percentage of total time per area for experienced observers are consistently higher than that of the novice observer, the significance of these figures is unknown.

Even if there is a clear cut difference between oculomotor activity of experienced versus novice observers, without information regarding their rates of target detection no conclusion can be drawn as to whether the oculomotor activity of experienced observers is of greater value than that of novice observers.

Summarizing the major observations made during data collection and analysis, the most significant finding of this study demonstrated that the scanning pattern of a typical US Coast Guard observer is a combination of "eye-lock" search and scanning patterns dictated by obstructions and environment configurations within the observer's field of view. The step by step scanning methods prescribed in training manuals are rarely used, and it is unclear whether a given search strategy employed by an individual is more effective than the technique used by another individual. Another point is that observers spend a great deal of their search time scanning areas midway to the horizon and beyond even though research has shown that small targets, such as rafts, are undetectable at that distance.

CONCLUSIONS

The continued use of human observers during search and rescue missions warrants the testing of currently prescribed scanning methods to determine their effectiveness. The results of this NAC Eye Mark Recorder study provided evidence that observers were not employing the systematic scanning patterns outlined in US Coast Guard training manuals, even though they were aware of the prescribed procedures. Perhaps statistical evidence supporting the effectiveness of various techniques would aid in promoting the consistent use of standardized methods. High target detection rates are the goal of improved scanner performance, therefore comparing the detection percentages of two groups, one using "free-search" and the other following systematic patterns, would determine which method is more effective.

Excessive dependence on obstructions and environment configurations as guides for search paths suggests a need for the artificial structuring of the observer's field of view. It has been shown that individuals in the cockpit of the HH-3F made three vertical sweeps as opposed to one made by the observers in the back of the aircraft. There is little doubt that this is a direct result of the additional geometric guides created by the three windows. By positioning a transparent grid-like pattern between the observer and his search scene, there would be more lines, or guides, to search along, resulting in a more systematic and complete coverage of the ocean's surface.

Observers should be instructed/trained to concentrate their searches within the area of the maximum detection range as determined by target type and environmental conditions. Scanning nearer the vehicle would provide better coverage of the entire area. Otherwise, it is possible that an observer could overlook a target near the vehicle, which would then be out of visibility range from the next leg of the search.

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APPENDIX A

QUESTIONNAIRES

VOLUNTEER AGREEMENT

I, ______________________________, having attained my eighteenth (18th) birthday, and otherwise having full capacity to consent, do hereby volunteer to participate in an investigational study entitled:

____

____

under the direction of ______________________________.

The implications of my voluntary participation; the nature, duration, and purpose; the methods and means by which it is to be conducted; and the inconveniences and hazards which may reasonably be expected have been explained to me by ______________________________, and are set forth below, which I have initialed. I have been given an opportunity to ask questions concerning this investigational study and any such questions have been answered to my full and complete satisfaction.

I understand that I may at any time during the course of this study revoke my consent and withdraw from the study without prejudice; however, I may be required to undergo certain further examinations if in the opinion of the attending physician such examinations are necessary for my health or well-being.

______________________________ ____________
Signature Date

I was present during the explanation referred to above as well as the Volunteer's opportunity for questions and hereby witness his signature.

______________________________ ____________
Witness' Signature Date

Hazards Noted: Procedure for mask removal in the event of impending crash has been satisfactorily explained.

____
Initials

DEPARTMENT OF THE ARMY
U. S. ARMY AEROMEDICAL RESEARCH LABORATORY
FORT RUCKER, ALABAMA 36362

UNCONDITIONAL CONSENT FOR USE OF PICTURE AND SOUND

The United States Government is granted the right to use, to the extent and for the purpose it desires, any pictures (still, motion, those transmitted via TV or recorded on video tape or otherwise) and sounds (vocal, instrumental, or otherwise) whether used together or separately, taken or recorded by or on behalf of the US Army Aeromedical Research Laboratory.

______________________ (DATE) ______________________ (SIGNATURE)

______________________ (HOME ADDRESS)

______________________ (MILITARY ADDRESS)

Above consent obtained by: ______________________ (SIGNATURE)

BIOGRAPHICAL DATA

1. ID No.:

2. Do you wear eyeglasses or contact lens? Yes No

   a. Are you: Near-sighted Far-sighted

   b. Do you have astigmatism? Yes No

3. Present Grade:

4. Age:

5. Total Coast Guard service in years:

6. To which craft are you presently assigned?

   a. HC-131 d. 41 ft UTB

   b. HH-3F e. 82 ft WPB

   c. HH-52A f. 210 ft WMEC

7. Total Search and Rescue experience (years):

8. Total Search and Rescue experience in past year:

9. Total Search and Rescue experience in past 6 months:

10. Total Search and Rescue experience in past 90 days:

11. Have you ever been to a formal school on Search and Rescue methods?

    Yes No If yes, how long was the school?

12. Have you ever read or studied the CG 414 manual? Yes No

13. How many consecutive hours do you perform duties as a lookout?

14. How many hours between lookout duty shifts?

15. How many hours of unit training have you received on lookout methods?

16. How many hours of unit training have you received on lookout scanning methods?

17. What is your opinion of your success rate on detecting targets during lookout duties? 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

18. Do you practice lookout scanning methods during other duties? Yes No

19. Have you performed lookout duties in both airborne and sea operations? Yes No

20. Do you have your own scanning methodology you use during Search and Rescue duties? Yes No

21. If the answer to No. 20 is yes, explain your search method. Use drawings if necessary.

RECORD FORM FOR VISION TEST

Date: ________________

ID No.: ________________________

Wear Glasses: Yes No

Contact Lenses: Yes No

Age: _____________

Acuity "FAR"	Right Eye 20/				Left Eye 20/					Both eyes 20/					
Color Perception "FAR"	A12		B5		C26		D6			E16			FO		
Lateral Phoria "FAR"	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Vertical Phoria "FAR"	1	2	3	4	5	6	7								
Acuity "NEAR"	Right Eye 20/				Left eye 20/					Both eyes 20/					
Depth Perception															

Remarks: ____

____

____

____

____

Tester: ________________________

APPENDIX B

EQUIPMENT AND MANUFACTURER LIST

LOCAM Model 51-0002 Camera
LOCAM Model 51-0002 DC Nicad Battery
Redlake Corporation
Photo Instrument Division
2991 Corvin Drive
Santa Clara, CA 95031
(408) 739-3034

Mini-Ranger III
Motorola, Inc.
Government Electronics Division
7402 South Price
P.O. Box 22050
Tempe, AZ 85282

NAC Eye Mark Recorder
NAC Film Motion Analyzer with Projection Head
Instrumentation Marketing Corporation
820 South Maripost Street
Burbank, CA 91506
(213) 849-6251
TLX 67-3205

NOVA 800 Computer
Data General Corporation
Southboro, MA 01772
(617) 485-9100
TWX 710 390-0309
TLX 94-8460

PBH-2 Armored Vehicle Crewman's Helmet
Gentex Corporation
Carbondale, PA 18407
(717) 282-3550

Sonic Digitizer Graph Pen
Science Accessories Corporation (SAC)
970 Kings Highway West
Southport, CT 06490
(203) 255-1526
TLX 96-4300

Systems 85 Digital Computer
Systems Engineering Laboratories
6901 West Sunrise Boulevard
Ft. Lauderdale, FL 33313
(305) 587-2900

025 Computer Display Terminal
Inc.
0
OR 97077

enerator Model 13-0007
poration
ument Division
Drive
, CA 95051
034

on Tester
cal Company, Inc.
VA 23803

APPENDIX C

GROUP DATA FOR ALL SEARCH POSITIONS

HH-3F Instrument Key

1.	RALT	Radar Altimeter
2.	BALT	Barometric Altimeter
3.	RMI2	Radio Magnetic Indicator 2
4.	AH	Artificial Horizon
5.	RMI	Radio Magnetic Indicator
6.	CLK	Clock
7.	AS	Airspeed
8.	VSI	Vertical Speed Indicator
9.	T&B	Turn and Slip
10.	AS2	Airspeed 2
11.	TACH	Tachometer
12.	OBS	Omni-Bearing Selector
13.	MCAU	Master Caution
14.	FUEL	Fuel Gauges
15.	EGST	Engine Status Gauges
16.	WRNG	Warning Lights
17.	RADR	Radar
18.	OFW	Opposite Front Window
19.	DFW	Direct Front Window
20.	SW	Side Window
21.	CB	Chin Bubble

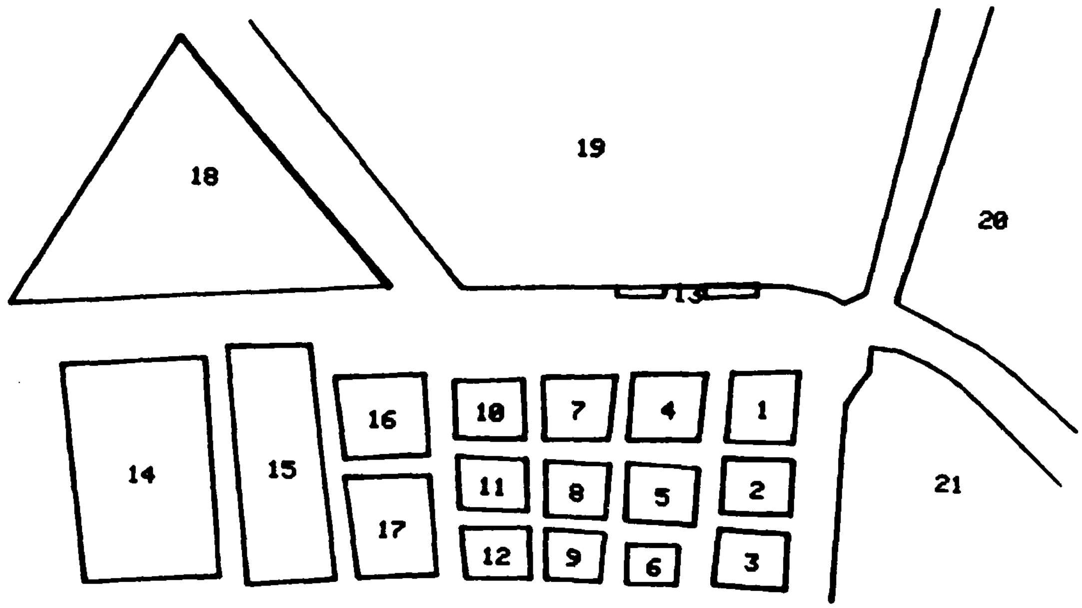

FIGURE C-1. HH-3F Pilot Panel.

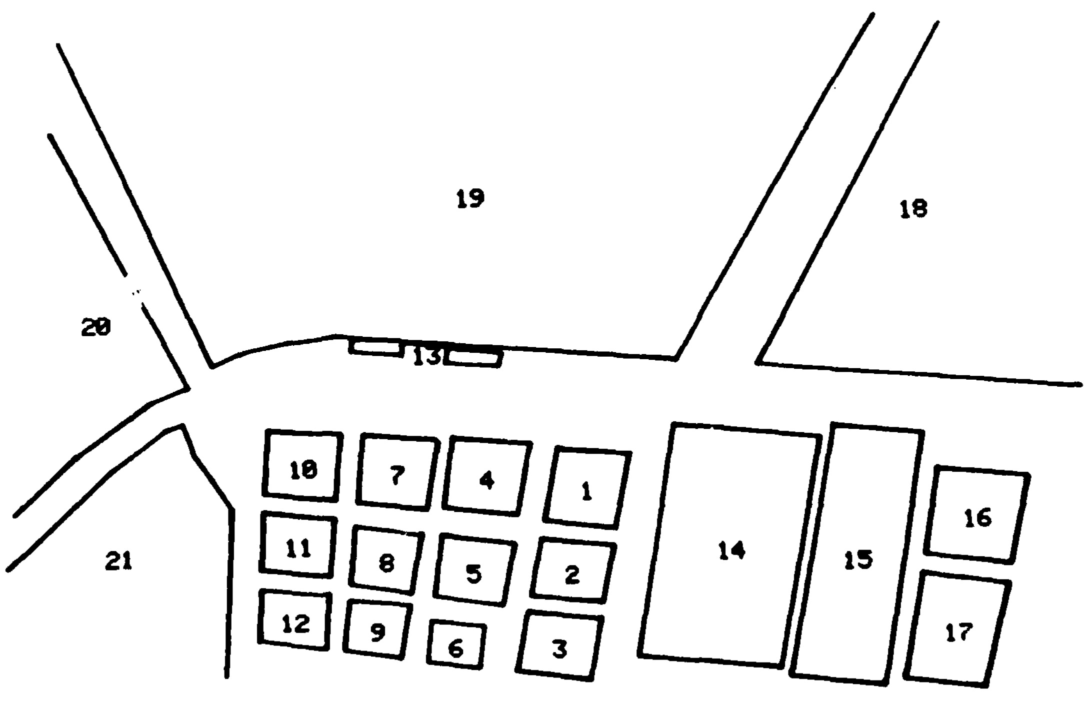

FIGURE C-2. HH-3F Copilot Panel.

TABLE C-1

GROUP STATISTICS SHOWING STATISTICAL VALUES COMPUTED FOR HH-3F PILOTS

AREA	FIXATIONS #	FIXATION %	MEAN DWELL TIME (MS)	TOTAL TIME %	CF %	SCAN MEAN (SECONDS)
RALT	21	0.6	293.7	0.3	0.4	13.3
BALT	19	0.5	375.0	0.4	0.4	18.1+
RMI2	18	0.5	300.9	0.3	0.4	12.2+
AH	13	0.3	326.9	0.2	0.3	13.8+
RMI	7	0.2	470.2	0.2	0.2	0.0
CLK	7	0.2	601.2	0.2+	0.2	26.9
AS	6	0.2	590.3	0.2+	0.2	5.6
VSI	14	0.4	422.6	0.3	0.3	12.6+
T&B	26	0.7	524.0	0.7+	0.7	23.2+
AS2	32	0.8	475.3	0.8+	0.8	14.6+
TACH	50	1.3	533.3	1.3+	1.3	13.0+
OBS	42	1.1	439.5	0.9+	1.0	13.0+
MCAU	12	0.3	371.5	0.2	0.3	16.3
FUEL	19	0.5	886.0	0.8+	0.7	9.8+
EGST	41	1.1	987.8	2.0+	1.6	10.9+
WRNG	88	2.3	590.4	2.6+	2.5	8.4+
RADR	89	2.3	379.7	1.7+	2.0	12.1+
OFW	108	2.8	485.7	2.6+	2.7	9.7+
DFW	1977	51.8	420.6	41.8+	46.8	2.4
SW	787	20.6	339.1	13.4+	17.0	3.5
CB	152	4.0	282.3	2.2+	3.1	6.7+
REST	285	7.5	464.8	6.7+	7.1	6.7+
TRAN	3813		104.9	20.1		

TABLE C-2

GROUP STATISTICS SHOWING STATISTICAL VALUES COMPUTED FOR HH-3F COPILOTS

AREA	FIXATIONS #	FIXATION %	MEAN DWELL TIME (MS)	TOTAL TIME %	CF %	SCAN MEAN (SECONDS)
RALT	10	0.3	687.5	0.4	0.4	2.5
BALT	19	0.6	243.4	0.3	0.4	8.5
RMI2	17	0.5	301.5	0.3	0.4	7.7
AH	13	0.4	359.0	0.3	0.3	2.1
RMI	8	0.3	312.5	0.1	0.2	5.0
CLK	12	0.4	340.3	0.2	0.3	9.8
AS	10	0.3	308.3	0.2	0.2	10.8
VSI	9	0.3	347.2	0.2	0.2	18.1
T&B	10	0.3	287.5	0.2	0.2	6.5
AS2	17	0.5	308.8	0.3	0.4	11.8
TACH	11	0.3	253.8	0.2	0.3	18.8
OBS	9	0.3	421.3	0.2	0.2	5.0
MCAU	8	0.3	229.2	0.1	0.2	11.9
FUEL	86	2.7	367.7	1.8	2.3	4.8
EGST	49	1.5	329.1	0.9	1.2	4.4
WRNG	20	0.6	254.2	0.3	0.5	5.7
RADR	33	1.0	386.4	0.7	0.9	4.0
OFW	177	5.6	391.9	3.9	4.8	5.7
DFW	1974	62.3	451.4	50.5	56.4	2.2
SW	415	13.1	514.3	12.1	12.6	3.8
CB	51	1.6	330.9	1.0	1.3	10.2
REST	211	6.7	381.7	4.6	5.6	4.4
TRAN	3169		119.3	21.4		

TABLE C-3

GROUP STATISTICS SHOWING STATISTICAL VALUES COMPUTED FOR HH-3F RIGHT DOOR/FLIGHT MECHANIC OBSERVERS

AREA	FIXATIONS #	FIXATION %	MEAN DWELL TIME (MS)	TOTAL TIME %	CF %	SCAN MEAN (SECONDS)
1	551	15.6	689.3	13.3	14.5	2.6
2	235	6.7	650.4	5.4	6.0	5.5
3	28	0.8	470.2	0.5	0.6	12.0
4	227	6.4	707.6	5.6	6.0	3.6
5	2220	62.9	800.7	62.4	62.7	2.5
6	216	6.1	949.8	7.2	6.7	6.0
7	-0-	-0-.	-0-	-0-	-0-	-0-
8	36	1.0	509.3	0.6	0.8	8.0
9	8	0.2	307.3	0.1	0.2	20.3
REST	6	0.2	916.7	0.2	0.2	2.5
TRAN	3527		38.2	4.7		

TABLE C-4

GROUP STATISTICS SHOWING STATISTICAL VALUES COMPUTED FOR HH-3F LEFT WINDOW/RADIO OPERATOR OBSERVERS

AREA	FIXATIONS #	FIXATION %	MEAN DWELL TIME (MS)	TOTAL TIME %	CF %	SCAN MEAN (SECONDS)
1	189	9.9	502.0	5.9+	7.9	3.7
2	264	13.8	1116.5	18.5+	16.1	3.4
3	-0-	-0-	-0-	-0-	-0-	-0-
4	171	9.0	630.4	6.8+	7.9	4.8+
5	1247	65.3	831.1	64.9+	65.1	2.7
6	6	0.3	465.3	0.2	0.2	30.0
7	-0-	-0-	-0-	-0-	-0-	-0-
8	29	1.5	566.1	1.0+	1.3	8.6+
9	-0-	-0-	-0-	-0-	-0-	-0-
REST	3	0.2	597.2	0.1+	0.1	0.0
TRAN	1909		21.5	2.6		

TABLE C-5

GROUP STATISTICS SHOWING STATISTICAL VALUES COMPUTED FOR 82-FOOT WPB OBSERVERS

AREA	FIXATIONS #	FIXATION %	MEAN DWELL TIME (MS)	TOTAL TIME %	CF %	SCAN MEAN (SECONDS)
1	130	5.1	1045.5	3.8+	4.4	3.5
2	514	20.1	1190.3	17.0+	18.6	4.6+
3	177	6.9	1739.6	8.6+	7.7	6.9+
4	233	9.1	1319.9	8.5+	8.8	3.8
5	1186	46.4	1434.0	47.3+	46.8	3.9+
6	246	9.6	1616.0	11.0+	10.3	5.5+
7	-0-	-0-	-0-	-0-	-0-	-0-
8	47	1.8	1112.6	1.5+	1.6	6.8+
9	-0-	-0-	-0-	-0-	-0-	-0-
REST	24	0.9	1274.3	0.8+	0.9	20.8+
TRAN	2557		21.3	1.5		

TABLE C-6

GROUP STATISTICS SHOWING STATISTICAL VALUES COMPUTED FOR 210-FOOT WMEC STARBOARD OBSERVERS

AREA	FIXATIONS #	FIXATION %	MEAN DWELL TIME (MS)	TOTAL TIME %	CF %	SCAN MEAN (SECONDS)
1	215	6.6	1726.0	7.3+	7.0	4.3+
2	1376	42.5	1168.0	31.8+	37.2	4.1+
3	21	0.6	333.3	0.1	0.4	8.8
4	133	4.1	1820.5	4.8+	4.5	6.0+
5	1428	44.1	1873.1	53.0+	48.5	4.5+
6	9	0.3	476.9	0.1	0.2	40.0+
7	7	0.2	1547.6	0.2+	0.2	18.5
8	30	0.9	1972.2	1.2+	1.0	5.0
9	-0-	-0-	-0-	-0-	-0-	-0-
REST	18	0.6	1497.7	0.6+	0.5	40.0+
TRAN	3237		14.8	0.9		

TABLE C-7

GROUP STATISTICS SHOWING STATISTICAL VALUES COMPUTED FOR 210-FOOT WMEC PORT OBSERVERS

AREA	FIXATIONS #	FIXATION %	MEAN DWELL TIME (MS)	TOTAL TIME %	CF %	SCAN MEAN (SECONDS)
1	101	7.3	9108.1	26.5+	16.9	7.4+
2	428	30.7	1801.2	22.2+	26.5	6.0+
3	43	3.1	1038.8	1.3+	2.2	5.2
4	53	3.8	6413.5	9.8+	6.8	10.5
5	710	51.0	1855.0	37.9+	44.5	4.0
6	42	3.0	884.9	1.1+	2.0	8.4+
7	-0-	-0-	-0-	-0-	-0-	-0-
8	-0-	-0-	-0-	-0-	-0-	-0-
9	-0-	-0-	-0-	-0-	-0-	-0-
REST	15	1.1	1416.7	0.7	0.8	12.9
TRAN	1392		15.1	0.6		

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